Opportunity

Test methods for the service life prediction of polymeric materials in outdoor exposures do not generate reliable or repeatable results.

They are expensive and time consuming.

Goal: Develop a test method which has the ability to accurately and precisely predict the in-service performance of polymeric materials designed for specific outdoor exposure in less than real time.

Why should you care?

Difficulty in assessing the environmental performance of products

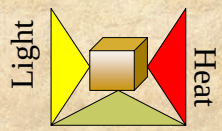
- **Results in barriers**
  - **to the market success of innovative products**
    - *Generic/commodity products*
    - *does not reward R&D investment*
  - **to realization of the economic cost of choices in building materials**
    - *Decisions based on first cost, not best value*
    - *Pressure to lower cost at expense of quality*
    - *65-75 B$/yr in repair, replacement of homes*

Traditional Metrology

Outdoor Aging (26 months)

Make Comparison
Outdoor
Vs.
Accelerated Aging

Accelerated Aging



No Correlation
Adjust Accelerated
Again Factors.

Current Reality:

Outdoor exposure

" This brings us face-to-face with one of the most perplexing problems concerned with outdoor weathering, that the weather does not duplicate itself. How can one ever expect a laboratory method to duplicate the weather when the weather can never duplicate itself" [Grinsfelder, 1967]

or

Laboratory exposure

" Successful laboratory simulation of the effects of weather on coatings, plastics and other materials has eluded scientists for over fifty years. Published literature report hundreds of attempts to duplicate and accelerate weathering effects and conclude that there is no substitute for natural weathering [Dreger, 1973]

"Current estimates of Service Life Prediction are Crude and there is Little or no Correlation between Laboratory and Field Exposure." RILEM State of the art Report, 1999.

Opportunity

Approach

Library Creation

Library Evaluation

Informatics

Have other scientific fields accepted reliability-based models for outdoor exposure?

Biology

Skin Exposure to Photons

- Dose versus Damage.
- 1 hour x no sunscreen = 8 hours with SPF 8
  = 40 hours with SPF40.

Cumulative Dosage Model

$$D_{total}(t) = \int_0^t \int_{\lambda_{min}}^{\lambda_{max}} E_o(\lambda, t)(1-10^{-A(\lambda)})\phi(\lambda)d\lambda \, dt$$

- $D_{total}(t)$ = Damage to material.
- λ_{min} and λ_{max} = minimum and maximum photolytically effective wavelengths
- $E_o(\lambda,t)$ = spectral UV irradiance from light source
- $(1\text{-}10^{-A(\lambda)})$ = spectral adsorption of specimen
- $\phi(\lambda)$ = spectral quantum yield of specimen
- $A(\lambda)$ = adsorption at wavelength λ

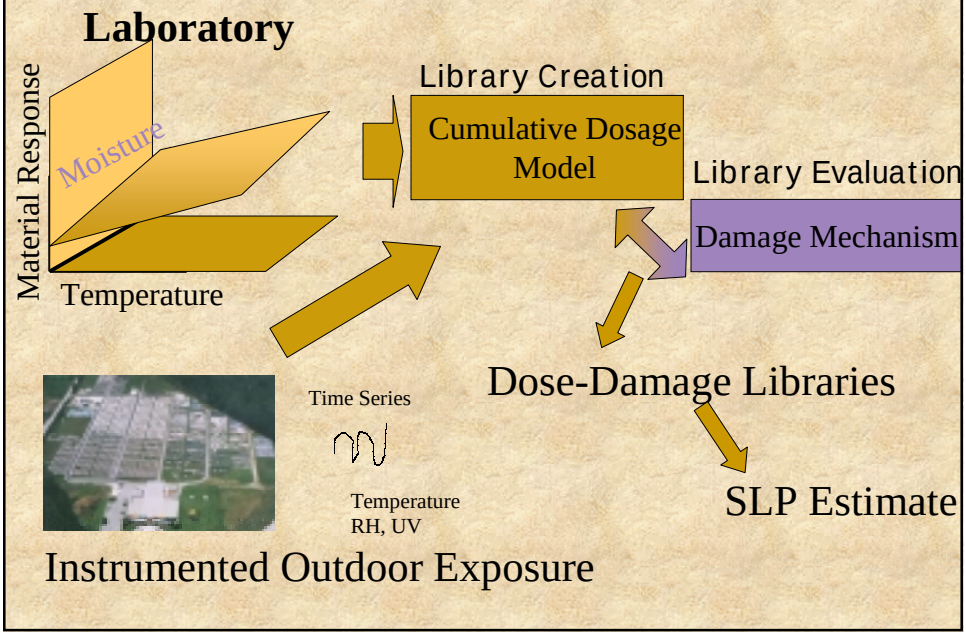
DOSE

Important Factors in Durability for Polymeric Materials in Outdoor Exposures

- Moisture/Relative Humidity.
- Temperature
- UV
- Mechanical Loading

From 1999 State-of-the-Art Report: (RILEM/ASTM)

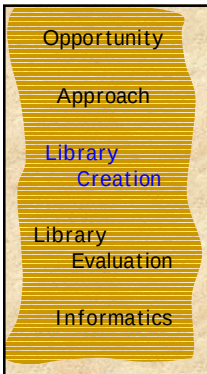
Reliability-Based SLP Methodology



Reliability-Based SLP Methodology

Advantages:

- Based on fundamental science understanding of the material behavior including failure
- Identification of critical components of exposure and materials
- Reliable, repeatable measurements
- Shorter time to develop understanding of environmental performance
- Predictive capability for any exposure conditions



Generating Libraries of exposure

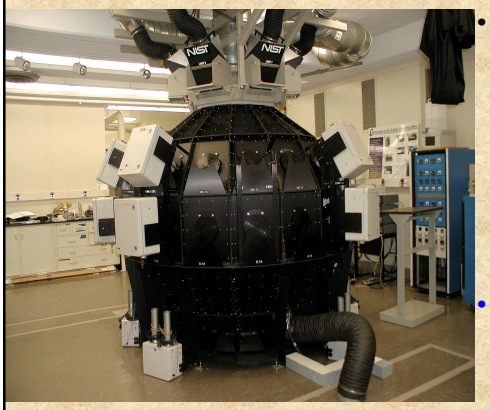
Need to separately control :

- UV (both wavelength and Flux)
- Humidity
- Temperature

If you pick 5 different levels of each variable, and three replicates at each condition,

> 3,000 samples for each formulation to expose and evaluate

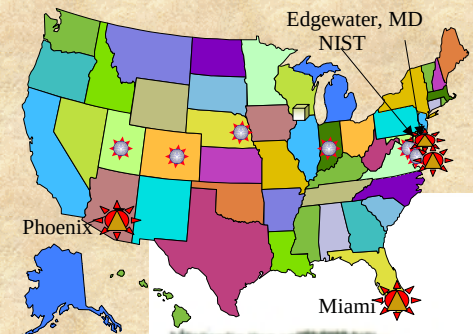
SPHERE: Simulated Photodegradation by High Energy Radiant Exposure



- 2 M Integrating Sphere Exposure Device
  - High Flux -8,400 W UV radiation. 25 "suns"
  - Large sample area-**300-500 samples**
  - 95% exposure uniformity between samples
- Temperature and relative humidity are well controlled
  - Up to 32 independent environments

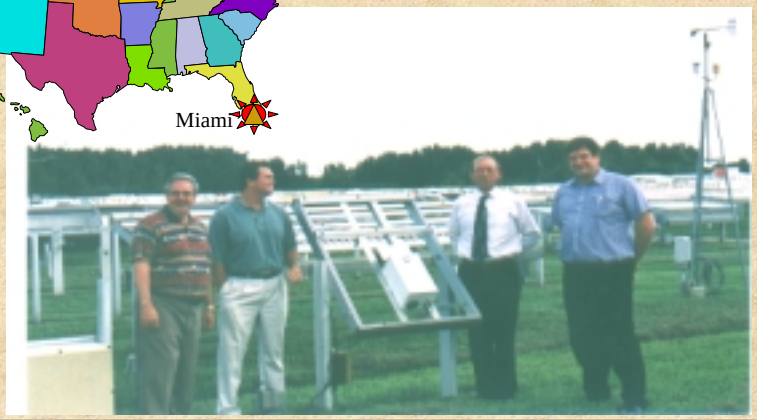
- Visible and Infrared Radiation removed
- UV-radiation broken down into wavebands
- Measurements of exposure conditions and degradation response highly automated

Solar Net Exposure Sites



- 11 sites; spectral solar UV data collected since 1997

•Collect 28 weather elements



Opportunity

Approach

Library Creation

Library Evaluation

Informatics

Evaluation of Exposure Libraries

Need at least three measures of each Sample:

Measure directly

Solve for

$$D_{total}(t) = \int_0^t \int_{\lambda_{min}}^{\lambda_{max}} E_o(\lambda, t)(1-10^{-A(\lambda)})\phi(\lambda) d\lambda \, dt$$

IR spectra, Gloss

UV Spectra

- No turn key solution exists to purchase
- No one manufacture makes UV, IR and gloss spectrometers

Develop our own:

- *Goal: Keep up with SPHERE and Outdoor exposures*
  550 samples/day,
  3 measures/ sample
  1600 spectra/day

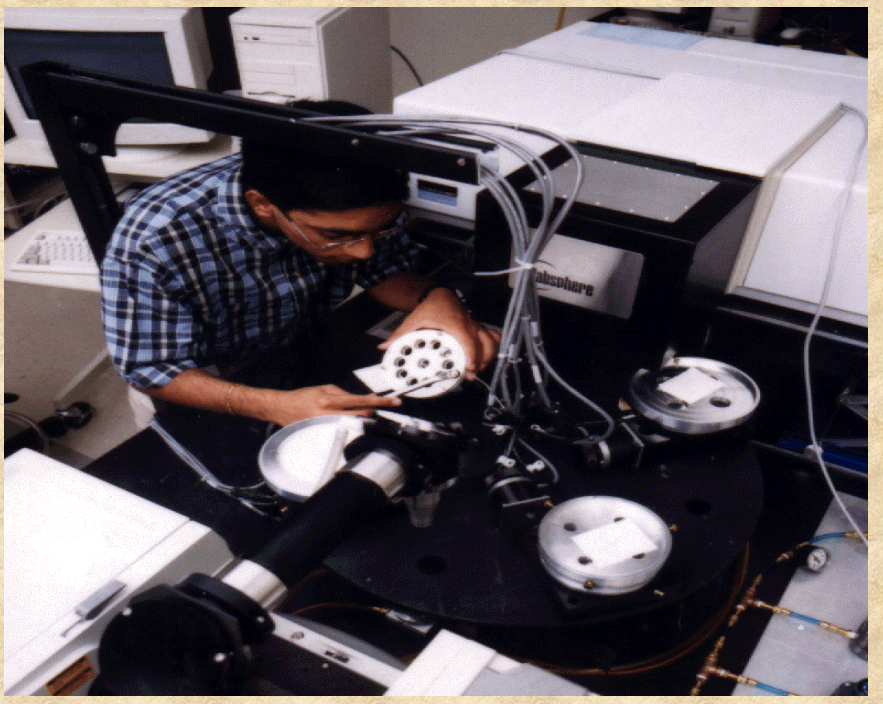
Focus: Automation & Minimize opportunity for operator error

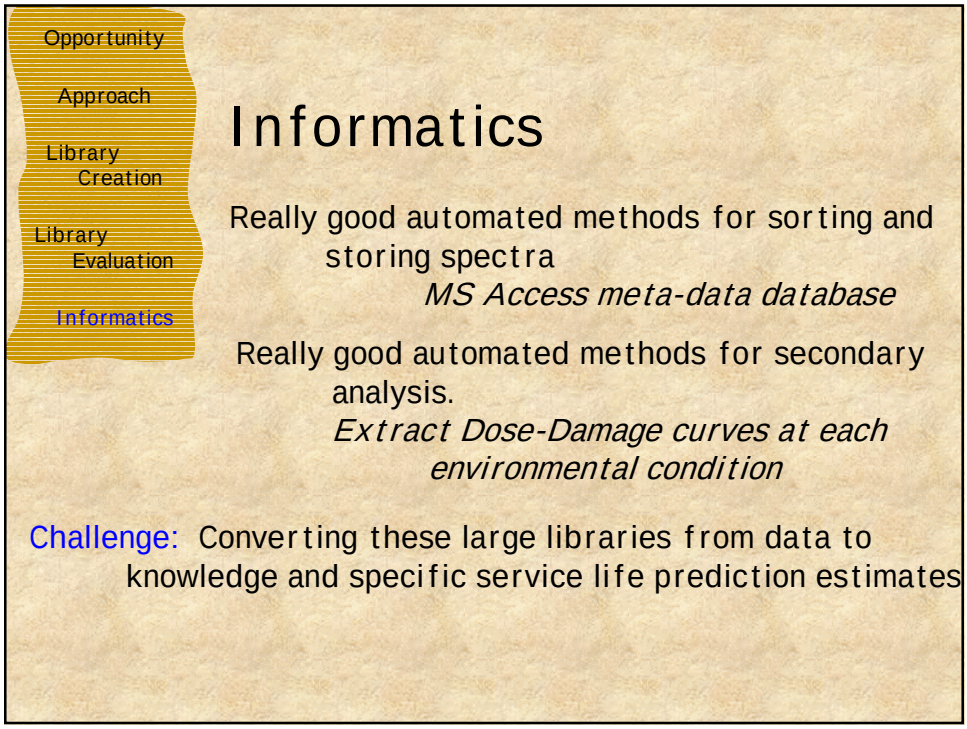
High Throughput Table

Features:

- Bar code sample tracking
- Control of FTIR and UV/vis,
  Two different manufactures
- Automatic sample positioning table to accommodate up to eight sample magazines.*
- Integrated informatics system to remotely store and catalog each spectra file
- 30 min/magazine

*a magazine is an assembly of 17 samples into a single package.




Opportunity
Approach
Library Creation
Library Evaluation
Informatics
Informatics
Really good automated methods for sorting and storing spectra
MS Access meta-data database
Really good automated methods for secondary analysis.
Extract Dose-Damage curves at each environmental condition
Challenge: Converting these large libraries from data to knowledge and specific service life prediction estimates